Design Standard
Basic HVAC System Design

Revisions Log:

Version	Date	Description of changes/updates
2	May 25, 2015	• Expansion of section on Sustainable Design • New section on Start-Up Training • New section on Documentation

Purpose:

The purpose of this document is to standardize the basic elements of the HVAC system design process. This design standard has the purpose of creating a consistent application of HVAC system design throughout the East Side Union High School District, therefore achieving a standard of quality for maintenance, energy efficiency, and reliability throughout all renovation and new building projects, as they are a long-term investment for the District.

HVAC systems shall provide a safe, comfortable and healthy environment for facility occupants while being energy efficient and inexpensive to maintain over the life of the building. Service life, energy efficiency, indoor air quality, comfort, maintenance cost, and flexibility are major considerations to be accounted for in the design of the HVAC system.

Design of ESUHSD's original campus facilities date back as early as the 1940's. For current renovation and new building projects, the HVAC system and its controls are expected to reflect a forward-thinking, contemporary design philosophy and aesthetic rather than emulating existing technology from the mid-20th Century.

Design Standard:

1. **Codes: Systems will be designed in accordance with the latest edition of the following codes:**
   - California Building Code.
   - California Mechanical Code.
   - California Plumbing Code.
   - California Fire Code.

- National Electrical Code; California Electrical Code.
- State of California Code of Regulations (CCR).
- Energy Efficiency Standards and Title 24 Regulations.
- Local City Amendments and Regulations.
- DSA – Department of the State Architect.

2. Standards – The following reference standards will be used for the design:

- AMCA – Air Movement and Control Association International, Inc.
- ANSI – American National Standards Institute.
- ARI – Air Conditioning and Refrigeration Institute.
- ASHRAE – American Society of Heating, Refrigeration, and Air Conditioning Engineers.
- SMACNA – Fire and Smoke Damper Installation Guide.
- SMACNA – Guidelines for Seismic Restraints of Mechanical Systems.
- SMACNA – Standards for Duct Construction.
- EPA – Environmental Protection Agency.
- NEMA – National Electrical Manufacturer's Association.
- UL – Underwriters' Laboratories.
- NFPA - National Fire Protection Association.
- NFPA 90A – Air Conditioning and Ventilating Systems.
- NFPA 101 – Life Safety Code.
- LEED – U.S. Green Building Council.

3. HVAC Calculation

- Utilize the following design conditions (San Jose, California) in calculating HVAC system capacities:
  - Outdoor: Summer 86°F, 66°F wb *, Winter 29°F

    * Use for cooling load calculations only; use normal weather tapes for energy compliance. Use 105°F ambient for outdoor air temperature for direct expansion HVAC equipment.
  - Indoor:
    - Classrooms, office areas and public spaces:
      - Summer: 72 - 76°F

        - Winter: 68 - 72°F
    - Kitchen/Servery:
        - Summer max: 75°F
        - Winter min: 60°F
  - Store rooms, electrical/mechanical equipment rooms and other non occupied spaces other than computer rooms and telephone equipment rooms, using thermostatically controlled exhaust fans if needed:
    - Summer max: 90°F
    - Winter min: 50°F
  - Server rooms, MPOE, MDF and IDF spaces:
    - Max: 85°F
    - Min: 50°F, max humidity: 95% non-condensing
- Lighting Loads: Lighting loads shall be calculated at CEC T-24 Watt per square foot values during preliminary design. Engineers shall execute final calculations upon selection of final lighting fixture selections.
- Equipment Loads: Equipment loads are variable and should be based on actual equipment to be installed in each location, or 1.5 watts per sq ft, whichever is greater. Engineer shall apply diversity factors so as not to oversize central HVAC systems.
- Thermal Mass: Thermal mass shall be considered during calculations as a method to offset cooling loads.
- U-Values for Walls and Roofs: Loads shall be calculated at CEC T-24 allowances during preliminary design. Engineers shall execute final calculations upon selection of final building façade materials.
- U-Values for Solar Heat gain Factors for Windows: Loads shall be calculated at CEC T-24 allowances during preliminary design. Engineers shall execute final calculations upon selection of final building façade materials. Internal shading shall not be used to reduce the load calculated. Fixed exterior shading shall be allowed to reduce calculated cooling load.
- Cooling system pick-up capacity: 10% of total load
- Heating system pick-up capacity: 25% of total load
- All calculations shall be completed utilizing DOE approved calculation software.
- Pipe sizing calculations: 4.0’/100’HD for main piping; 3.5’/100’ HD for branch piping; 7 fps maximum velocity in occupied spaces.

- Duct sizing calculations: equal friction method - 0.1"/100' for main ductwork (never exceed 2,000 feet per minute); 0.08"/100' for low pressure branch ductwork (never exceed 800 feet per minute). Lower velocities may be needed for acoustical purposes.
- Return air systems – Return air ducts shall be sized on the equal friction method at 0.08"/100' (never exceed 1,500 feet per minute). Design plenum return air systems for low pressure drops. Design transfer air systems at 250 feet per minute to minimize pressure drop at grill faces, and at 500 fpm at open air spaces across the net free area. For multiple, cascading transfer openings the total pressure drop shall not exceed the allowable pressure drop for an individual opening.
- Acoustical and Vibration Calculations:
  - Acoustical calculations shall be completed by a professional specializing in the science of sound transmission, acoustics, and vibration.
  - Design shall conform to ASHRAE Chapter "Sound and Vibration Control", latest edition, and the ESUHSD Acoustical Design Standards.

4. Outside Air Make-up and Ventilation

- Utilize CEC T-24 and/or ASHRAE Standard 62 (whichever is most stringent), latest edition, to determine outside air ventilation flow rates. Indicate quantities of minimum outside air on all equipment schedules.
- Outside air for ventilation and make-up shall be brought from a fresh source of air. Outside air openings and operable building systems shall be at least 18" above adjacent surfaces, and located at a minimum of 15'-0" from any permanent or temporary points of:
  - Cogen plant exhaust
  - Boiler exhaust
  - Kilns
  - exhaust air
  - plumbing vents
  - areas of objectionable odor
  - locate away from loading docks, parking lots, adjacent roadways, etc.
  - 30'-0" separation from non-environmental exhaust systems (as defined by the CMC) such as kitchen exhaust, lab fume hood exhaust, garage exhaust, etc. Increase separation where openings are downwind from sources listed above.
- Design outside air intakes to eliminate the possibility of water carry over. Always utilize drainable weatherproof type louvers at intakes.

- Units shall be equipped with a fully modulating 100% OA economizer and with a separate minimum OA intake system for guaranteeing proper levels of OA intake through all ranges of system operation.
- Provide CO_2 monitoring to accommodate demand based ventilation to reduce energy use. Monitors shall be connected to the BMS. Consider for large occupancy areas such as:
  - Gymnasiums
  - Theaters
  - Student Unions / Commons / Centers
  - Auditoriums / Multi-purpose Rooms / Lecture Halls
  - Lobbies
  - Cafeterias
- Determine if natural ventilation can be utilized for comfort cooling either by itself or as part of a mixed-mode system. Prior to locating intakes, consider:
  - pollution sources
  - acoustical interferences
  - security
  - airflow patterns via CFD modeling

5. Ventilation During Construction

- In order to improve indoor air quality, specify building flush-out during and after interior finish work. The ventilation system should be operational after drywall installation (but turned off during operations which generate high amounts of dust) and during painting, carpet and furniture installation. The HVAC system must operate continuously, providing the maximum amount of outdoor air. The building shall continue to be flushed out for a period of not less than 30 days prior to occupancy. To the extent possible, all installations resulting in substantial generation of VOC's should be completed before this time frame.

  The return inlets must be protected with filtration of sufficient efficiency so as not to contaminate the air distribution system. If continuous flush out is not possible, then temporary ventilation shall be provided to areas with high-VOC activities. If temporary ventilation is not practical, then four days of continuous flush out shall be required after wet product application such as paints and caulks, and before the HVAC system is temporarily turned off for testing. Brief interruptions of a few hours would be acceptable in emergencies during the third or fourth day. The flush-out schedule shall be extended to compensate for delayed VOC-producing installations. HVAC systems must be reset to maximum OA after hours and when no testing is occurring.

The cost of power, equipment maintenance, etc. during this flush out shall be the contractor's responsibility. Following the completion of the minimum 30 day purge and prior to occupancy, the HVAC systems shall be returned to like new condition, filters replaced with new, and the contractual warranty period shall not be adversely affected.

6. Equipment Selection and Design Considerations

- Specify system types based on:
  - Lifecycle cost analysis to include first cost, operating cost, maintenance cost, energy cost
  - Reliability
  - Temperature control
  - Noise level
  - System complexity appropriate to maintenance capacity
  - Service life of 25 years minimum
  - Susceptibility to vandalism and theft
- General Requirements, Siting, Service Access
  - Provide an integrated design so that each element of the building is carefully considered. Produce a holistic solution.
  - Utilize shading, landscape, canopies, blinds, building thermal mass, etc. to reduce heating and cooling loads and minimize equipment sizes.
  - Locate equipment indoors wherever possible. Where it is not possible due to cost constraints, aesthetics or other hardship, equipment may be located outdoors obstructed from view and architecturally shielded.
  - Rooftop equipment:
    - Rooftop equipment may attract birds that nest in/around the units, and damage insulation by using pieces to build nests. Designers who specify the installation or repair of rooftop equipment shall also specify the installation of enclosures to protect new and existing piping, motors, etc. from bird infiltration. Specify wire cages, solid metal, or any other material that will withstand the weather, moisture, etc.
    - Specify hail guards to protect coils.
    - Specify roofing system walk pads around units.
    - Specify PVC condensate drains, to prevent copper theft.
  - Provide service disconnect switches immediately adjacent to units.

- Provide proper clearance for maintenance, with lighting and convenience outlets per code. Minimum service area clearance around all sides of units shall not be less than 4'-0" clear.
- Provide elbow cleanouts at condensate drains, and a union between unit and inlet of trap.
- Coils shall be designed with adequate service access for maintenance and replacement.
- Consider the use of ultraviolet lamps at AHU cooling coils to kill bacteria and mold that may grow in air handling units. Ultraviolet lamps will not only kill bacteria and mold but also have the advantage of reducing maintenance for coil cleaning.
- Ensure safe and reasonable service access. Provide labeling for ease of access in concealed conditions. This includes HVAC equipment concealed within suspended ceilings, hard lid ceilings, and other hidden conditions, and applies to any equipment requiring service access for maintenance or testing annually or more frequently (e.g., fire/smoke dampers).
- Provide temperature-controlled exhaust fans for electrical rooms containing transformers and/or other heat-generating equipment (as Code allows).
- Provide heating and ventilation for gymnasia and locker rooms; do not provide cooling.

- Fans:
  - Fans shall be selected on a stable point of operation of the fan curve. Fan selection shall be based on methods in the ASHRAE Handbook, most recent edition.
  - Selected motor sizes and speed should provide a 15% safety factor for deviation in fan static pressure and future airflow increases.
  - Static pressure of fans shall be determined from pressure drop calculations (based on the most hydraulically remote location) including:
    - ductwork
    - fittings
    - diffusers/grilles
    - ductwork accessories
    - system effects
    - specialties and appurtenances
    - discharge velocity pressure

- Select fan sound and pressure levels to assure quiet operation per ESUHSD acoustical design requirements.
- Fume Hood Exhaust Fans: Fans shall be UL listed for such service. Provide explosion proof systems with appropriate coatings to prevent chemical action on fan and housing. Discharge shall be marked as hazardous and in a suitable location.
- Exhaust Fans: Exhaust fans shall be centrifugal roof ventilators with direct or belt-driven drives, installed on curbs with level mounting surface.
- Provide 4" dryer vent connection for dryer exhaust.

• Cooling Coils
  - Design direct expansion and chilled water coils on basis of a nominal 400-500 foot per minute face velocity. Design heating water coils on basis of a nominal 600 foot per minute face velocity.
  - All cooling coils shall be piped counterflow of refrigerant against airflow.
  - Select the Cv of each coil control valve at design conditions.
  - Design with upward water flow through coil, provide air vents at all high points of coils to eliminate trapped air.
  - At a minimum design with isolation valves on supply and return, two or three way control valve based on pumping system design, drain, flexible connections, and temperature gage. Provide balancing valves as needed.

• Air Distribution Devices
  - Supply Diffusers:
    - Preferred method of air distribution due to aspiration and entrainment of room air (reduction of drafts and more even room temperature profiles) as well as the ability to distribute air in many different directions.
    - Supply air grilles shall be sized based on manufacture's airflow, noise criteria, mounting height, and pressure drop data.
    - Do not aim supply air diffusers at thermostat controls.
  - Supply Grilles:
    - Avoid wall grilles where possible. Wall grilles have a lack of aspirating qualities and when discharging in cooling can create a perceived feeling of drafts. Where designed, use care. Utilize a larger width to height aspect ratio for maximum induction of room air. Utilize double deflection type grilles to maximize adjustability.

Do not throw air longer than 15-20 feet in rooms with low ceilings (below 9 feet).

- Supply air grilles shall be sized based on manufacturer's airflow, noise criteria, mounting height, and pressure drop data. Do not exceed 500 feet per minute.

- Return Air Grilles
  - Locate to aid in contaminant displacement.
  - Design for low pressure loss in return plenum systems to assure that rooms do not get over-pressurized.
  - Return air grilles shall be sized based on manufacturer's airflow, noise criteria, mounting height, and pressure drop data. Do not exceed 400 feet per minute for ducted systems and 250 feet per minute for plenum return systems.
- If transfer grilles are used, they should be arranged with lined ductwork between to minimize noise and light transmittance. Transfer grilles and associated ductwork shall be sized for air velocities not exceeding 500 feet per minute.
- Coordinate placement of grilles with reflected ceiling plans, including but not limited to light fixtures, sprinkler heads, technology devices, audio/visual devices, fire detection devices, security detection devices, architectural features, etc.

- Ductless Split System Air Conditioners for IDF/MDF/MPOE Rooms
  - Site the unit above the entry door. By doing so, precious wall space in the room is preserved for technology equipment, any water leaks will not drip onto technology equipment, and the unit will have adequate service access.
  - Provide local, wired, wall-mounted thermostatic control.
  - Provide monitoring through the DDC EMS, with alarm notification above 80°F.
- Sound Attenuation and Vibration Control
  - Utilize sound traps or acoustical duct lining to mitigate noise attributable to HVAC equipment where required.
  - Size of sound traps and length to be designed after completion of calculations, preferably by an acoustical engineer.
  - Length of acoustical lining to be designed after completion of calculations, preferably by an acoustical engineer.
  - Provide vibration isolation devices as required to meet ASHRAE recommendations for vibration transmission.

- Pumps
  - Provide systems with two pumps. Deliver 100% capacity with both pumps operating in parallel. When one pump shuts down, a single pump shall be capable of providing 75-80% of the total capacity. Due to cost considerations, standby pumps are not required unless there is a specific concern for redundancy.
  - For economical design and energy efficiency, end suction, base mounted pumps and in-line pumps should be used for most systems except when the systems become very large.
  - Dynamic head of pumps shall be determined from pressure drop calculations (based on the most hydraulically remote location) including:
    - piping
    - fittings
    - valves
    - coils
    - system effects
    - specialties and appurtenances
  - Pumps shall be capable of being removed for maintenance without having to drain the entire system or remove piping.

7. Temperature Control and Zoning

- Selected buildings, and/or areas within selected buildings, shall be connected to the campus DDC control network. Refer to Integrated Automation Facility Controls Design Standard for additional criteria. Areas not selected for automated controls will be designed with local controls. Coordinate design requirements early in the schematic design phase.
- Individual temperature controls will be based on function, exposure, and Owner request.
- Each corner exposure (NE, NW, SE, and SW) shall be on a separate temperature control zone.
- Each conference room, lobby, classroom, lecture hall, break area shall be on a separate temperature control zone.
- Perimeter closed office zones shall include no more than five offices along the same orientation. This requirement may be relaxed when utilizing variable volume diffusers and terminal units are used primarily as a means of pressure control and reheat; however, group variable volume diffusers along the same orientation.

- Restroom exhaust fans shall be controlled via occupancy sensor, with a 30 minute shutoff time delay. Provide easy service access to the power pack.
- Locate thermostats per mechanical engineering design best practice. Local thermostatic controls access is to be limited to authorized personnel (Maintenance personnel, and the school's Head Custodian). Automated thermostatic controls may be provided with user override capability. Refer to 23 09 53 23 09 23 Direct Digital Control System for HVAC Design Standard and 23 09 53 Pneumatic and Electric Control System for HVAC Design Standard for additional information.

8. Sequence of Operations

- Sequences shall be determined to minimize energy use and take advantage of low part-load conditions that occur frequently at the campuses.

9. Specialty Pressure Requirements and Exhaust Systems

- Specific rooms shall be designed to be at a negative pressure to adjoining spaces and to be exhausted 100%. These rooms include but are not limited to: restrooms, certain labs (confirm with activity and use), certain science classrooms (confirm with activity and use), kitchens, janitor closets, copy rooms, food service rooms, loading docks, locker rooms, shower facilities, photograph rooms and dark rooms, art classrooms (confirm with activity and use), refrigeration machinery rooms, boiler rooms, etc.
- Areas with products of combustion need removal of the combustion byproducts and a source of combustion air.

10. Central Plants

- Central plants reduce overall energy costs, limit noise and vibration away from occupied spaces, reduce maintenance to a single location for boilers, chillers and pumps, and increase the aesthetic quality of the remainder of the campus. ESUHSD does not have campuswide central plants; ESUHSD's HVAC conditions vary from mostly zone-based decentralized units to some multizone units, with only a handful of building-based boilers and chillers (e.g., for certain theater facilities).
- In the event that a project includes development of a central plant, equipment selection should be industrial commercial grade. If the original design does not provide capacity for the entire campus plus growth, consideration should be given in the design for future expansion.

11. Food Service Facilities

- The kitchen shall be designed with separate exhaust systems for each hood allowing each hood to be separately controlled. Fans shall be at the end of the exhaust system and located in the exhaust duct. Exhaust airflow shall be at a rate of 1500 feet per minute minimum to create a capture velocity. No duct accessories are allowed in the kitchen exhaust system except to facilitate duct cleaning.

- Kitchen Grease Exhaust: Fans shall be UL listed for such service. Provide with drain. Consider location of kitchen smoke exhaust with regards to campus views, deterioration of building façade, and odors. Ductwork must meet CBC, NFPA, and CA Fire Code.
- Provide separate exhaust systems for dishwashing. Ductwork shall be non-corrosive stainless steel and pitched for drainage. A duct drain shall be provided at the low point of the ductwork. Do not trap water in the duct.
- Exhaust ductwork shall be specifically designed of materials compatible for kitchen grease exhaust
- Make up air can either be provided from make-up air handlers or by transfer of air from adjoining spaces, Code permitting.
- The make-up air and exhaust air systems shall be interlocked.
- Prevent walk in freezer drain lines from freezing by specifying heat tape wrap, covered with insulation. This application should begin at the evaporator drain outlet and extend as far as needed to prevent line freeze.
- Prevent walk in freezer door failures and icing by specifying heater cable around the door and a threshold heater.
- Evaporative cooling (EC) systems for kitchens will generally be located at the roof, discharge vertically and feed into the kitchen area. Rooftop EC unit(s) shall be single-zone, packaged, factory-fabricated unit(s), prewired, consisting of cabinet and frame, supply fan, furnace section including economizer, controls, air filters, direct/indirect evaporative cooler, roof curb, flexible connectors and vibration isolators. Filters shall be disposable type, 2-inch thick, preformed, pleated, nonwoven cotton batting material. Direct evaporative media shall be constructed of glass matt; UL approved with UL 900, class 2 rating. Flame spread index of 5 maximum.

12. Documentation

- Construction Layout Drawings: Direct the contractor to prepare and submit layout drawings to coordinate installation and location of mechanical equipment.

  Prepare composite drawings showing all equipment on a single sheet. The architectural floor plans, reflected ceiling plans, and access floor layout plan shall form the base for the coordination drawings. Prior to completion of Drawings, coordinate proposed installation with the Architect, structural requirements, and other trades (including FFE, electrical, plumbing, fire protection, ceiling systems, and raised floor system), and provide required maintenance access.

- As-Constructed Drawings: Final construction drawings and specifications, together with final layout coordination drawings, with as-constructed information added, are to be submitted as record drawings at completion of project. Plans are to incorporate all addenda items and change orders.
- Closeout Documentation: Submit HVAC authority certification of inspection. Include documentation of on-site mechanical testing that was performed.

13. Start-Up Training:

- Specify preparation of a formal training program for operating staff prior to the scheduled start-up date. The program will consist of the design, start-up, and operation of the HVAC systems. The training program is to be coordinated with production of the operation and maintenance manuals. Operations and Maintenance data is to be available for training sessions.
- Specify provision of 4 hours of on-site training in the operation and maintenance for installed system and major pieces of equipment. Verify this quantity with the Facilities Director during the construction documents phase of design.

14. Sustainable Design Practices

- ESUHSD has a desire to design and construct sustainable buildings and grounds. Sample sustainable design opportunities are provided in the table located in the ESUHSD Sustainability Design Standard. Each strategy needs to be integrated appropriately into their respective projects. Development of design strategies for each item is beyond the scope of this HVAC Design Standard and requires careful consideration for proper application. The District will select on a case by case basis the projects that are to achieve LEED™ certification, CHPS certification, pursue utility company incentive grants, etc. The design team shall discuss green design and certifications with the Facilities Director during the project's programming phase, in order to make a recommendation and seek the Director's approval for pursuit of certifications and incentive grants.

  Engineer shall provide consulting and construction assistance to the District as needed to achieve LEED™ certification, CHPS certification, pursue utility company incentive grants, etc.

  a. LEED™ certification: Provide design and documentation as required by United State Green Building Council to achieve the targeted certification.
  b. CHPS certification: Provide design and documentation as required by the Collaboration for High Performance Schools to achieve the targeted certification.
  c. Savings by Design energy incentive financing from PG&E.

Refer to Savings by Design Participant Handbook, published by PG&E. Create and submit to PG&E Savings by Design application(s).

i. Provide energy modeling software and simulations required by the Savings by Design Program.
ii. Establish the Title 24 baseline.
iii. Demonstrate to PG&E the energy model and gas and electric energy savings in excess of Title 24 minimums.
iv. Complete the Savings by Design contract with PG&E for available rebates to the owner.

d. Other certification, incentive and grant programs: Provide design and documentation as required to achieve the targeted certification, incentive financing, grants, etc.

Approved Manufacturers:

Not Applicable

Substitutes Allowed:

Not Applicable

Associated Design Standards and Construction Specifications

- Acoustic Design Standard
- Sustainability Design Standard
- Division 22 Plumbing Design Standards
- Division 23 HVAC Design Standards
- Division 25 Integrated Automation Design Standards
- Division 26 Electrical Design Standards
- Division 27 Communications Design Standards
- Division 28 Electronic Safety and Security Design Standards
- 01 91 00 Commissioning Design Standard
- 01 91 13 Commissioning Requirements Construction Specification

End of Document